MAPPING OF THE QUALITY STREAM IN THE PRODUCTION PROCESSES WITH THE USE OF THE BPMN

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Abstract

The article depicts the use of the BPMN (Business Process Model and Notation) in the graphic presentation of the quality flow in the production processes. The main purpose of this project was to conduct a validation of the material flow in the separated production subsystem as well as the identification of the areas which generates the biggest quality loss. The BPMN enables the realization of business processes' maps and the use of software tools can help with building the model and conducting the validation processes. In further steps there is also a possibility to run a simulation in the different conditions. In the article author focuses on the first step of modelling - the mapping of the representative production process including quality aspects.

Keywords: Production system, improvement of flow continuity, productivity

1. INTRODUCTION

Mapping of the processes has a broad usage in the service and production sectors. Mapping is mainly used whilst analyzing the flow of material, information, capital and value stream (for example: VSM method - Value Stream Mapping [10]). Processes' mapping is a graphic presentation of correlations between the objects. Depending on the method used, the purpose can differ. It can be modelling of the stream processes, validation of model's compatibility, verification of correctness, analysis (of efficiency, productivity or anything else) as well as the implementation of the supporting systems (like IT). Mapping has a broad usage because it can easily show the relation between objects. In the analysis of dynamic systems it is very important to reflect the relations between objects. Identification of the source of the incompatibility and creation of analysis of systems is as hard as the complexity level of the system. System's complexity depends on the amount of the components. It also depends on the level of complexity of the relations between objects and on the level of relations between the system and its' surrounding [5]. Complexity of system is influenced by the purpose's function. According to the Klir's definition we can present basic systems and complex systems [6]. Other authors [9] use definition of "big system" whilst analyzing the object made of many components (with a lot of relations between them). Verbal description of the complex system is quite hard and take a lot of time. It is also hard to understand it by listener. Graphical form is easier to adopt, and by using icons we are able to present the model with a certain order and go through the consecutive steps of the process. The map is the most popular of graphic presentation of the models. Mapping of the processes can concern the identification of the current status of the process. On this step, there are flows presented in the real structure. Identification of the current status predates the mapping process of the next status. On the map of the next status there is the presentation of the structure of the optimal flows and objects for the targeted status and also there is a need to make an improvement plan. In this plan it is necessary to set the certain tasks and designate people responsible for exact tasks, but also point the deadlines for the exact actions. In the last step there is a need to conduct the verification of the results and it have to be stated if the provided changes brought assumptive effects. If the results are not valid - there is a need to conduct the identification of the causes to be able to correct modeled system to achieve improvement. If results are valid - it is important to control following results on the daily basis.

Mapping of the systems may be executed on the three different levels: 1 - visual mapping, 2- analytical mapping, 3 - executive mapping [3]. Visual map reflects to the strategical level and it presents the most important streams, objects and the main purpose. On the visual map there are rarely presented the elements of the transaction subsystems. Analytical map pertain to the tactical level, and in comparison with the visual map - it is more detailed. There are some subsystems included (Loop, Multi-Instance, Ad-Hoc, Compensation) and there are every kind of events enlisted. Executive mapping pertain to the operational level and it is a map which includes all the possible events and flows possible. The executive map is the most detailed map and its' implementation in the informatics' system can help whilst verifying the correctness of flows, actions and the order of the tasks. Making a detailed map and using IT tools (for example. ADONIS) can help with conducting the efficiency analysis in a certain unit of time. Modelling of the processes enables monitoring, recording and interference (in case of delays, loops) as well as elimination of the errors.

The main purpose of this article is to present the first step of the mapping process of the quality stream with the use of BPMN. In this publication the quality stream is consist with the requirements, which is achieved by the consistency of the crafting process in the separate steps of the production process. The quality is the inherent set of the hierarchic consistency from the consecutive production steps. The level of the rating indicator is influenced by: the quality of the consecutive processes, the quality of stocks and components of the crafted product. In this case - quality term is non-deterministic random variable of the single events in the simultaneously considered list of stochastic processes which occur in certain time.

2. BUSINESS PROCESS MODELLING NOTATION (BPMN) - INTRODUCTION

Business Process Modelling Notation (BPMN) is a graphic tool which can be used whilst mapping and modelling the business processes. Business process is a straight sequence which can lead to execute a certain good - material (for example product) or immaterial (like information). BMPN is used in correlations and implementation of the service and production processes for the IT language. BPMN is a standard evolved by OMG (Object Management Group). The final version of the notation which is BPMN 2.0 has been published in the January 2011 [2, 3]. It is a standard which enables description of the processes in the understandable way and it allows to present them in the very specific and certain way. This duality is really important nowadays because in a lot of organizations it is important to use human, machine and IT resources in the most productive and efficient way. The quality of optimization depends on the quality of modelling of the real systems [3]. Meaning of the proper modelling is equal to the complexity of studied object. Modelling on the first step is based on the identification of lack of efficiency - in the *lean* philosophy there is an identification of 3M waste (muri, mura and muda). It is a diagnostic step which is a base for optimization or re-engineering of the processes. Proper rating of the current status has significant influence on potential implementation for the improving solutions.

In the quality area there are some tools used: 8D sheets, Ishikawa diagrams, Pareto, quality houses, Shewhart's control cards and some others [4]. However these do not have vital mechanism which can support reduction of generated incompatibilities. Nowadays the most popular form used to define flows is graphical form which can be transformed into the IT language to conduct system's validation. BPMN is a standard which is helpful whilst creating the visual definitions of flows and processes. It is easily recognizable on the operational stage as well as the tactical and strategic stages. Moreover, creation of the flow and processes map whilst using BPMN icons and transferring gathered data to IT platform enables conducting simulation and monitoring. Research and verification of the objects' statuses using the IT tools is not as risky as implementing changes to the "live" organization. Validation of proposed changes using the virtual object is less risky than using the real object. Using IT tools also enables to estimate what resources do we have and what human, finance, material, machine and energetic resources we need. It is also possible to enlist the KIP (Key Performance Indicators) to a process and then study its' values. All of those values made BPMN popular in making the map of quality stream in the certain production subsystems.

3. DEFINING OF THE MAPPED PRODUCTION SYSTEM

Analyzed system is a convergence setup in which there are some sets of basic streams of components, stocks and energy. In the model there is not analysis of "know-how" stocks or human resources. There is only an analysis of machines and relations between product and quality. On the first step of the building process there are not aspects caused by limitation of efficiency. It is important to have enough stocks of expected efficiency.

Analyzed production system SP is defined as a set:

$$SP = \left\{ E , A , X , Y , R \right\} \quad (1)$$

where: E - set of SP stocks;; A - stocks' attributes SP; X - parameters of SP input; Y - parameters of SP output; R - relations between: E, A, X and Y in the SP area.

Moreover:

$$E = \left\{ \left\{ E_1^1, E_1^2, ..., E_1^{N_1} \right\}; \left\{ E_2^1, E_2^2, ..., E_2^{N_2} \right\}; ...; \left\{ E_N^1, E_N^2, ..., E_N^{N_N} \right\} \right\} \quad (2)$$

where: $E_1^{i_1}$ - elements of the 1 set (machine) which has been assigned in according to the executive technology process, for example cutting - set N_1 - amount of cutting machines, $E_2^{i_2}$ - elements of the 2 set, for example N_2 - amount of the edge press.

$$A = \left\{ \left(a_1 \sim E_1^{N_1} \right) | \, y_{M,N}^{K}; \left(a_2 \sim E_2^{N_2} \right) | \, y_{M,N}^{K}; ...; \left(a_n \sim E_n^{N_n} \right) | \, y_{M,N}^{K} \right\} \quad (3)$$

where: a_n - attribute dependent on $E_n^{N_n}$ whilst using the element (or set of elements) from $y_{M,N}^{K}$.

$$X = \left\{ D^K, K \,|\, D^K, D^S, S \,|\, D^S, D^P, P \,|\, D^P, R^X \right\} \quad (4)$$

where: D^K - suppliers of the input components; K - input components dependant on D^K; D^S - suppliers of the input stocks; S - input stocks dependant on D^S; D^P - suppliers of the Energy; P - stream of Energy dependant on D^P; R^X - relations between X set.

$$Y = \left[\begin{array}{cccc|cccc|cccc|cccc}
y_{1,1}^{1} & y_{1,2}^{1} & \cdots & y_{1,N}^{1} & y_{1,1}^{2} & y_{1,2}^{2} & \cdots & y_{1,N}^{2} & y_{1,1}^{...} & y_{1,2}^{...} & \cdots & y_{1,N}^{...} & y_{1,1}^{K} & y_{1,2}^{K} & \cdots & y_{1,N}^{K} \\
y_{2,1}^{1} & y_{2,2}^{1} & \cdots & y_{2,N}^{1} & y_{2,1}^{2} & y_{2,2}^{2} & \cdots & y_{2,N}^{2} & y_{2,1}^{...} & y_{2,2}^{...} & \cdots & y_{2,N}^{...} & y_{2,1}^{K} & y_{2,2}^{K} & \cdots & y_{2,N}^{K} \\
\cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\
y_{M,1}^{1} & y_{M,2}^{1} & \cdots & y_{M,N}^{1} & y_{M,1}^{2} & y_{M,2}^{2} & \cdots & y_{M,N}^{2} & y_{M,1}^{...} & y_{M,2}^{...} & \cdots & y_{M,N}^{...} & y_{M,1}^{K} & y_{M,2}^{K} & \cdots & y_{M,N}^{K}
\end{array} \right] \quad (5)$$

where: $y_{M,N}^{K}$ - single final product for which K, M and N indexes are: different size, different models and destination and also variety of the additional options. Moreover, $y_{M,N}^{K}$ is a single column matrix which consists of the elements of the Bill of Materials structure.

Prestented production system SP has been used whilst the mapping process of the quality stream in compliance with BPMN. On the first step, addition of the values to the final product ($y_{M,N}^{K}$) there has been a visual map projected, just to be able to set the amount of the points in the quality control.

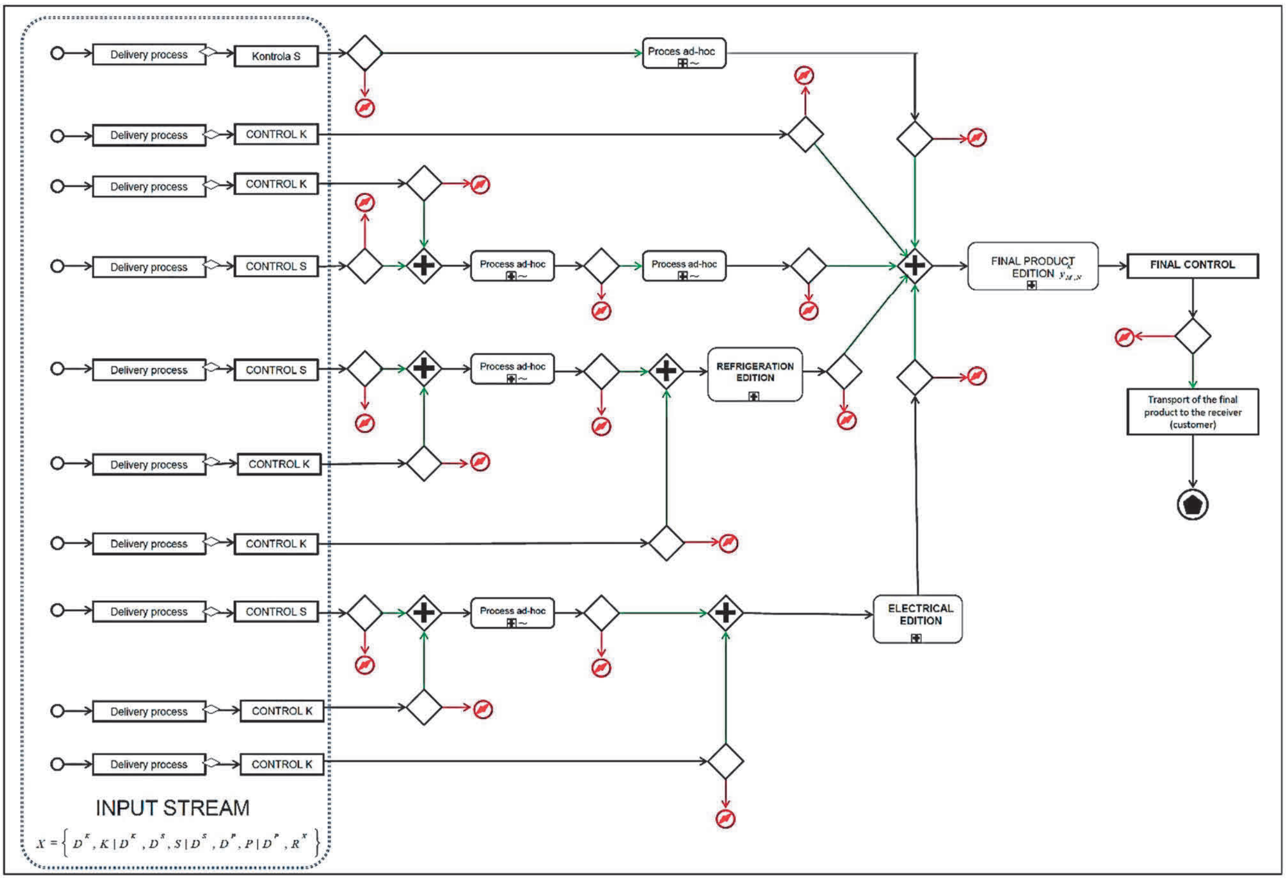

Figure 1 Visual map of the analyzed process in compliance with BPMN

In the production process there are about 600 different kinds of final products. Production process is customized and dedicated for the only one client at the same time. Due to great variety of final products, there is no “stockroom” production. There are three groups of criteria for division of the final products: size, destination (and model), additional options. There are about 450-650 different subsystems which make one final product. About 15% of these are the components delivered by the suppliers. Components are not processed in the production process. These are only edited on the certain step of the production process. The rest of 85% are the elements which are produced whilst analyzed system of stocks. By the stocks sets we understand: wires, steel plates, gaskets bought in the mb, different kind of the powder-paints and others. Production process takes place in 9 different nests. Each of the nest is responsible for the different process of production. Main production processes are: cutting process, edging process, weld process, isolation process, painting process, edit process (electrical and refrigeration). On the final phase there is six-steps process of editing of the final product. Streams of components and stocks have been mapped and details of the production process has been ignored.

4. DESIGNATION OF THE CRITICAL QUALITY STREAM

Visual map presented on the graphic shows the scale of the quality problems in the certain example. We can notice that in the analyzed system there are five independent streams which joins with each other on the final editing step of production process. Because of the fact that the system meets the terms of the complex system [5] there is a need to disintegrate for the components of the stream flows. On the assigned, single stream flows on the next step there has been conducted the analysis of critical path. This analysis is based on the gathered historical data and it allowed to set the sub-stream of the value in which there was the biggest loss caused by incompatibility. **Ad hoc** processes (which are the serial-parallel production systems) in the analytical view are the systems between repeated tasks (processes and measurements). If there is a repetition of the measurements for the same variable value (in different conditions or in different time) - a factor is repetitive as well. In the example provided for the ad-hoc processes there are a lot of the same events (processes, measurements) made on the same elements (machines, semi-finished products). These are creating the group of the "factors of repetitive events". Moreover - provided events are in relation with each other. Interpretation of the final results and interactions between them is not dependent on the "difference between factors between groups" or "factors of repetitive events". To make the step of exuding the critical path easier, it has been decided to ignore the effects of the interaction between single ad hoc processes. Ignoring the interaction has been based on the Fisher idea. Ineffectual combinations of levels were not considered in the model. This kind of model has been named "hierarchical system" in which the classification criteria is determined by the transition path. Due to the formula (6) for each and every path there is a need to set the amount of expenses generated by quality incompatibilities. The highest value of the costs will set the stream in which quality losses are the biggest burdens.

$$X_S = C_{B^1} \cdot B^1 + C_{B^2} \cdot B^2 + \ldots + C_{B^n} \cdot B^n \quad (6)$$

where: X_S - is the sum of expenses which are a result of the occurrence of B^n quality errors in the path $S = 1;2;3;4;5$ when $S = 1$ for the first path; $S = 2$ for the second path etc. B^n - the amount of n-error in the n point of control. C_{B^n} - single value of the B^n error, when the value of the cost which results from the occurrence of B^n errors is a constant random variable with f_{X_S} density. Then:

$$P(X_S \le x) = P\left(C_{B^1} \cdot B^1 + C_{B^2} \cdot B^2 + \ldots + C_{B^n} \cdot B^n \le x\right) \quad (7)$$

$$P(X_S \le x_o) = \int_0^{x_o} f_{X_K}(x)dx \quad (8)$$

It is possible to indicate the predicted value of the expenses incurred for the errors in the certain path of the formula (9):

$$EX_S = \int_0^{\infty} x \cdot f_{X_S}(x)\,dx \quad (9)$$

The greatest expected value for $S = 1;2;3;4;5$ will indicate the critical path which will be under decomposition in the next step of the quality improvement in the certain process.

5. CONCLUSION

The main purpose of "projecting for quality" is creation of optimized system of tasks in the area of projected product, projection of the production line and projection of the crafting quality [7]. Producer is responsible for all these areas of organization. That is why the producer is responsible for the general quality of the product. This quality should be accepted by the customer. Lean production focuses mainly on the elimination of muda, mura and muri losses. Majority of the lean toolbox focus on the improvement of efficiency of processes and crafting systems. Quality in lean manufacturing is one of the analyzed parameters in the production process. In the real production objects, quality analysis are mainly deterministic and there are no relations between the influence of the efficiency (increase or decrease) changes for the dynamic of these changes (for the process or the product). In the [8] publication there is a presentation of the analysis of the efficiency's increase (10%)

in the chosen stream of production with the decrease (47%) of the probability of achieving the constant quality level. Basing on the calculations published in [8] we can notice that the diagram of relations between efficiency and quality is not a linear function. Analysis of the quality parameter without the parameters of analyzed production system is incompatible with the general theory of complex systems [5, 6]. Proper validation of the models which are the reflection of the reality should consider all the influences and main relations [11]. Presented model of the real object is a graphical presentation of the system of convergence. The map made of the elements compatible with BPMN has a visual role and is a first step in the building of analytical map. On this step there is a detailed definition of all input streams possible and there are some mathematical models created to rate the quality of the defined input components. Use of the set (9) allows to determine the path in which the biggest costs are generated. In the next step there will be an analytical map developed for the designated path. In other words - next step of the mapping process will be executed (accordingly to the BPMN).

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